Three-dimensional Chalcogenide photonic crystals created by direct laser writing and chemical vapor deposition

Lifeng Chen[1], Xu Zheng[1], Mike P. C. Taverne[1], Y.-L. Daniel Ho[1], Chung-Che Huang[2], Daniel W. Hewak[2] and John G. Rarity[1]

[1]Merchant Ventures Building, Department of Electrical and Electronics Engineering, University of Bristol, United Kingdom.
[2]Optoelectronics Research Centre, University of Southampton, Southampton, United Kingdom.

Introduction

Rod connected diamond (RCD)[1], which is known to exhibit the largest full PBGs among all designs[2] with the same index contrast, has been investigated but remains a significant challenge to create[3]. Here, we use Direct Laser Writing[4] method to fabricate polymeric (n = 1.52) RCD templates and characterize its band structure via an angular-resolved spectroscopy. High refractive index photoresist and/or materials will be identified. Here, we intend to begin with chalcogenide (n = 2.4:1) backfilling via chemical vapor deposition technique [5] to realize the full photonic bandgap photonic crystals.

Characterization of templates

❖ MIT photonic-bands (MPB) calculation of RCD bandstructure shows a partial band gap at 1550 nm in Γ-X' direction and the measurement range in terms of scattering angle (see Fig. 1a). The insert defines the Brillouin zone of RCD showing the principle directions (X', U', L). Fig. 1b shows the dimension of polymeric template fabricated by direct laser writing system, where the lattice constant a = 1.25 μm, 11 periods in plane, and 6 periods in vertical.

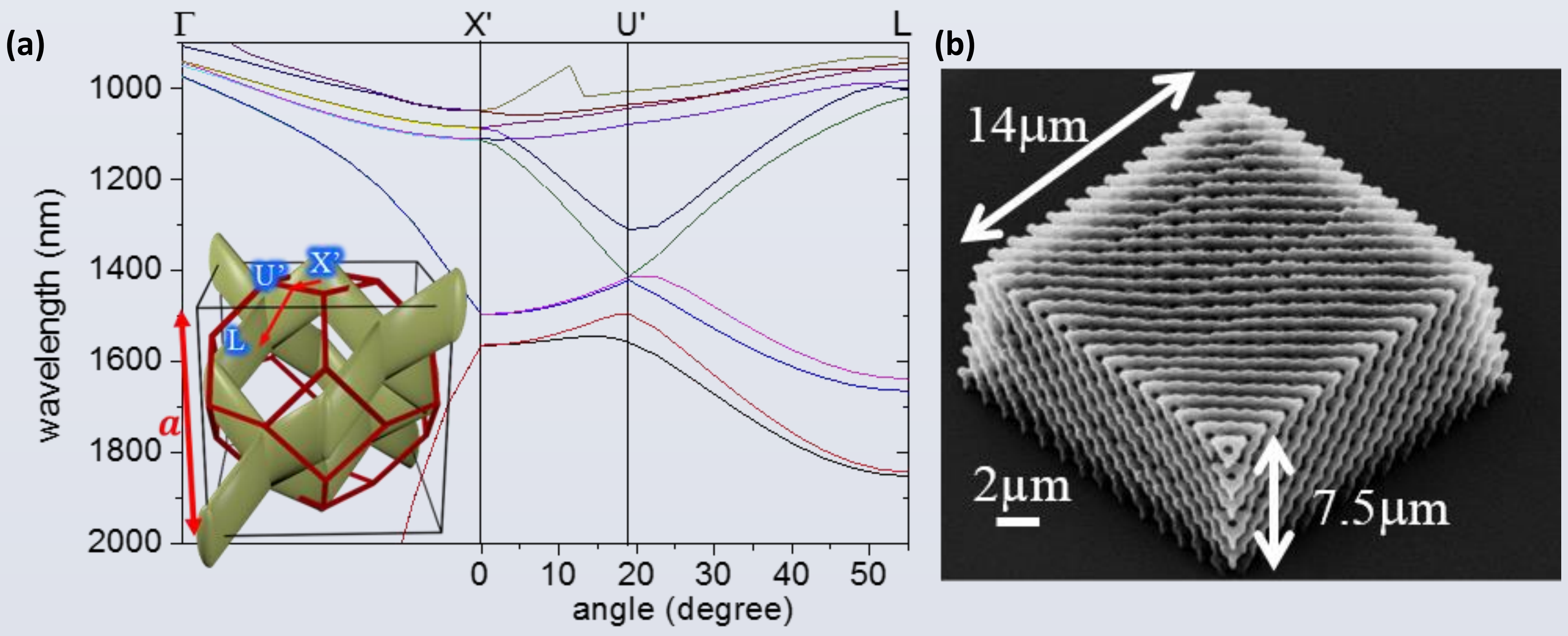


Figure 1

❖ The reflection (transmission) spectrum shows a 25% peak (dip) at around 1500 nm wavelength in normal incident (0° at X' point) as shown in Fig 2a. Fig. 2b is the reflection spectra against collection angles, which fits well with band structure data [6].

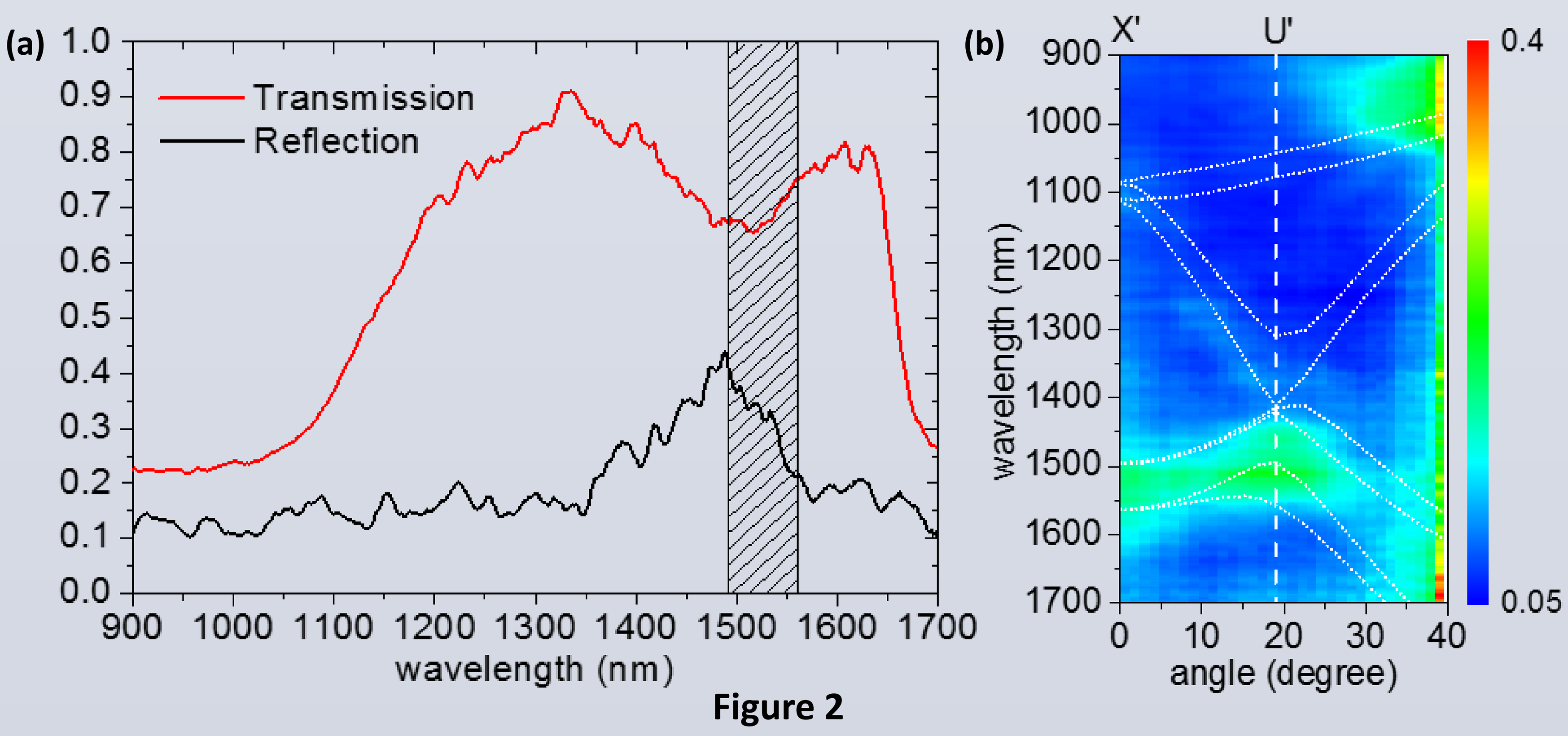


Figure 2

Chalcogenide back filled inverse structure

❖ Step 1: Direct laser writing of polymeric 3D photonic crystal templates.

❖ Step 2: 3D templates backfill with Ge-Sb-S Chalcogenide materials via chemical vapor deposition (Fig. 3).

❖ Step 3: remove polymer templates with solvent or thermal decomposition.

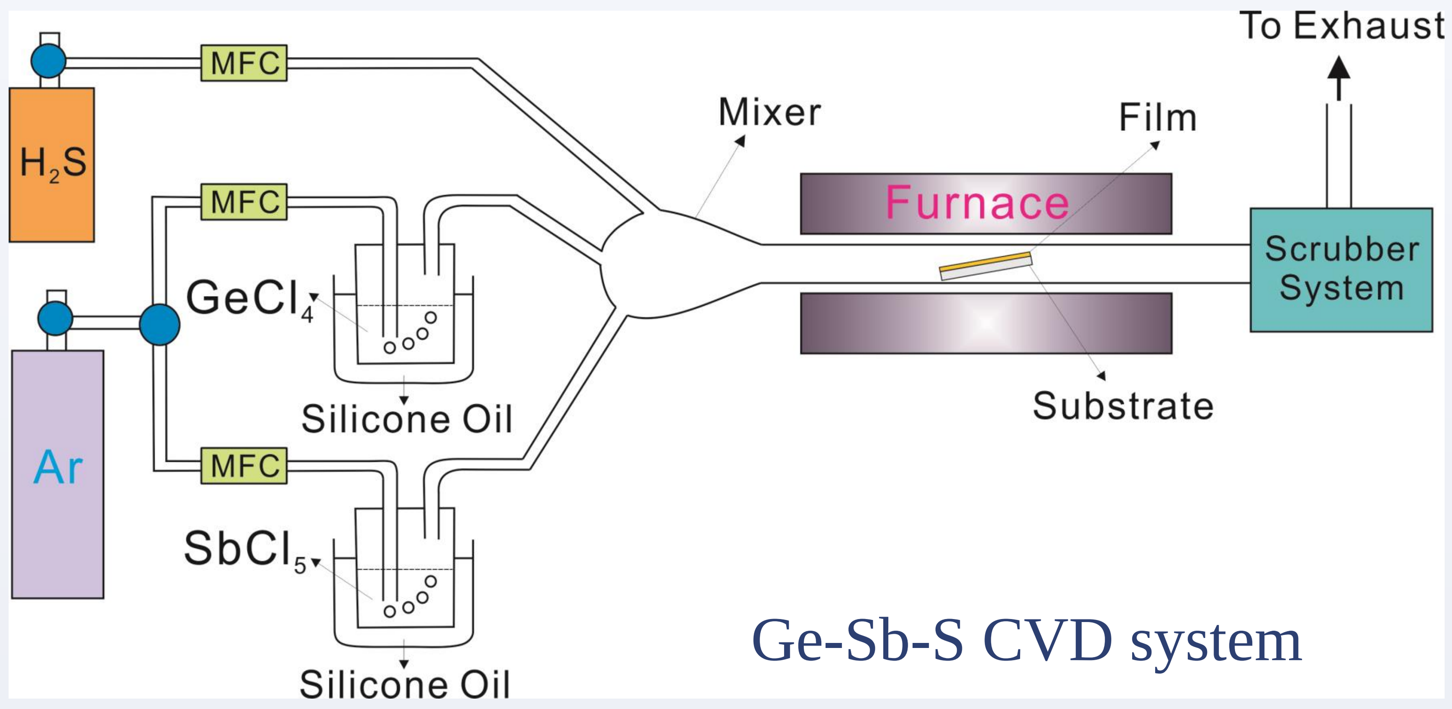


Figure 3. Schematic diagram of CVD system used for Ge–Sb–S thin film deposition.

❖ Preliminary results of polymeric woodpile (Fig. 4) and RCD (Fig. 5) templates backfilled with chalcogenide material. FIB cross-section of both structures backfilling using CVD deposition of Ge-Sb-S confirms 100% infilling and the conformal nature of the process. (Black area is remaining polymer and gray parts are backfilled chalcogenide material.)

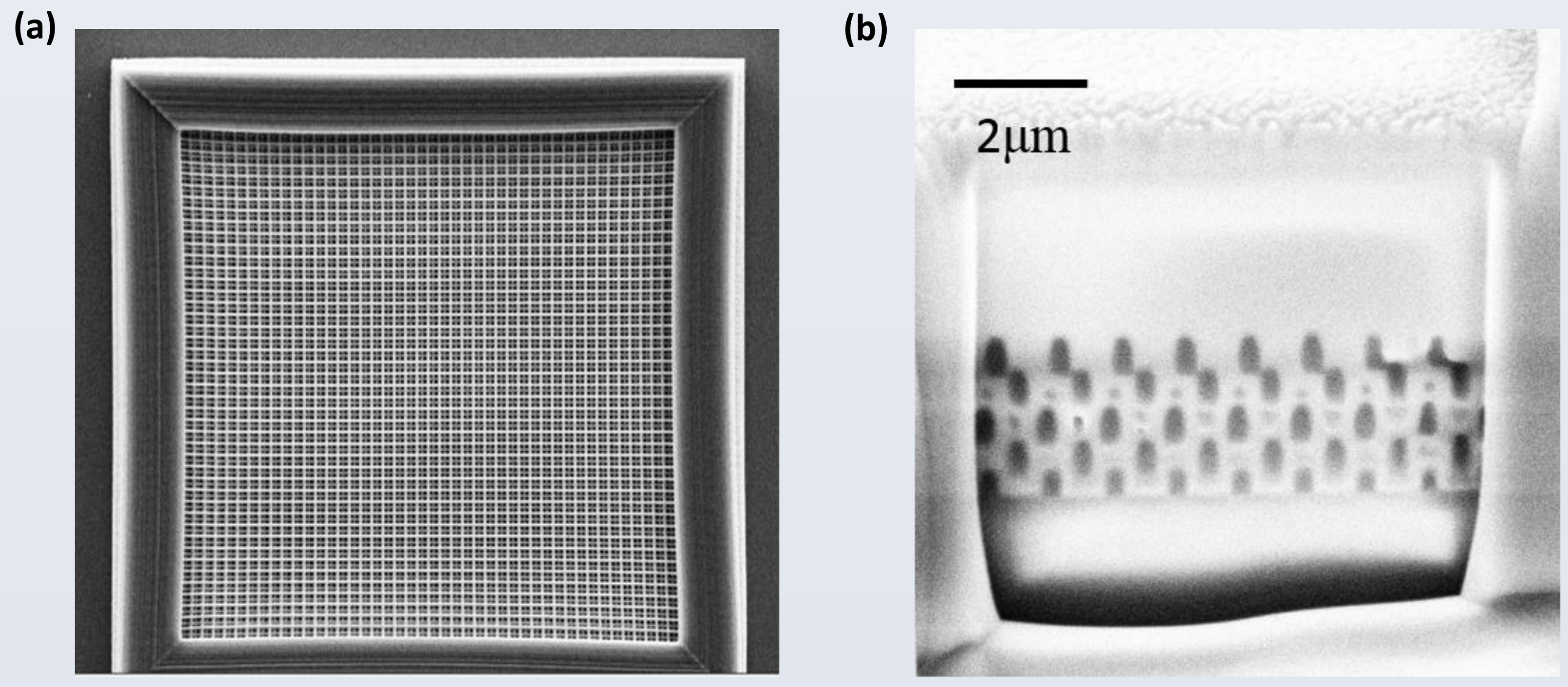
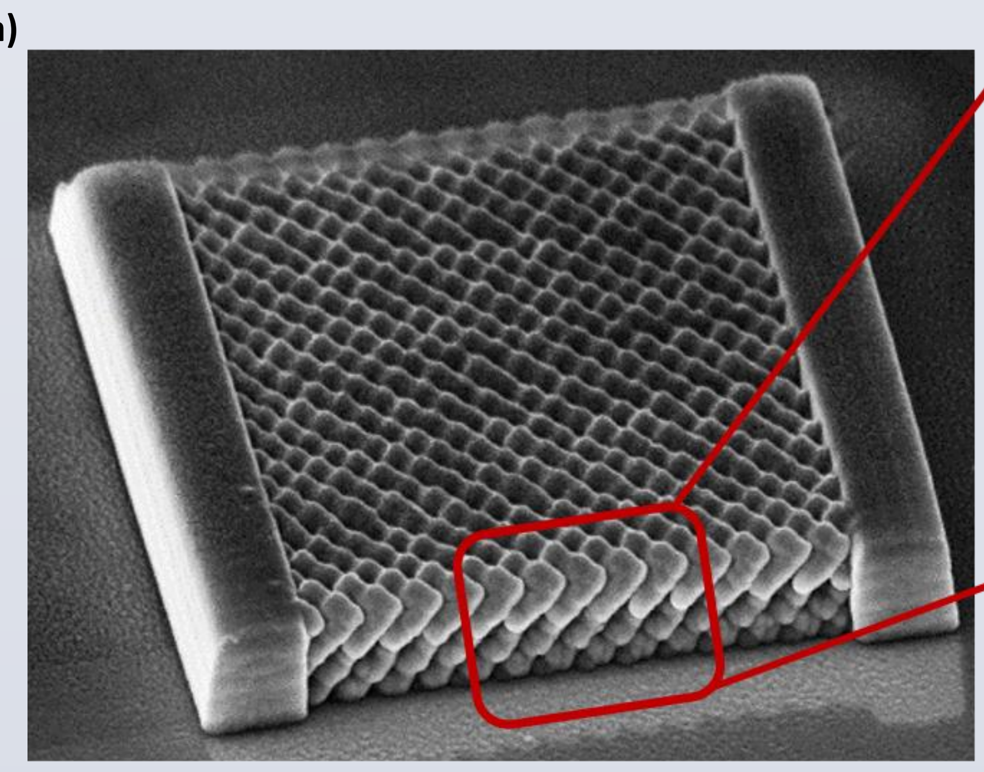


Figure 4. (a) woodpile structure template before backfill process; (b) an SEM cross-section image fabricated by focused ion beam showing the quality of infilling.



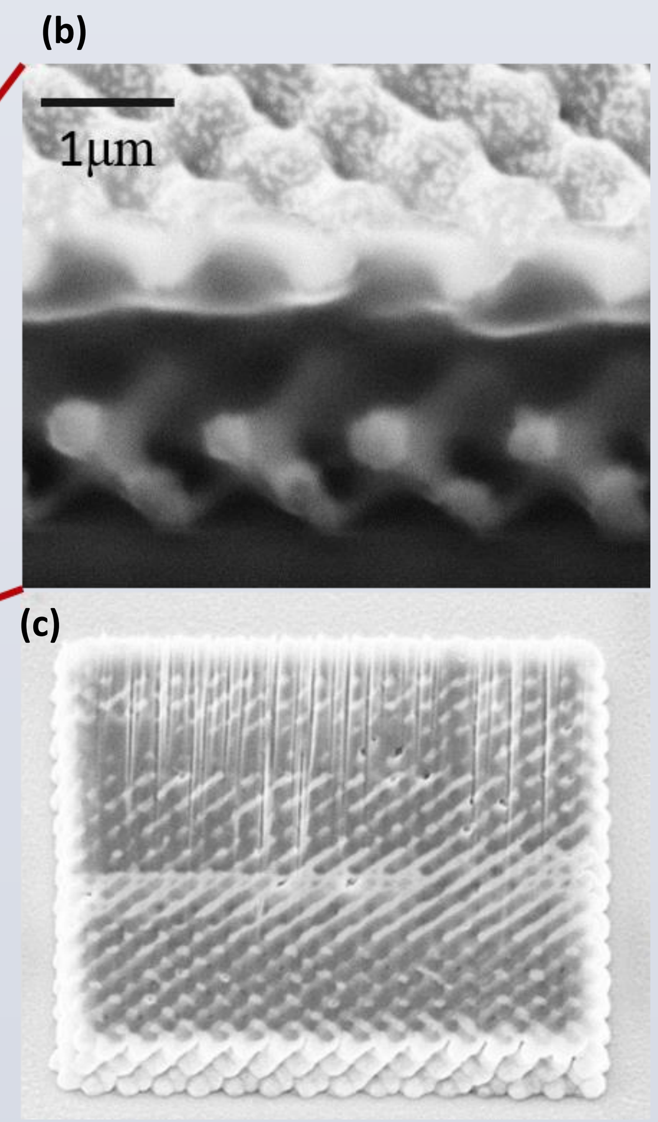


Figure 5. (a) RCD template surrounded by chalcogenide material; (b) SEM cross-section image show the 3D architecture, where bright parts are chalcogenide material; (c) the top layer was removed by focused ion beam to show the quality of back-filling, bright parts are chalcogenide material.

References

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